

—

[illegible]

FREQS.H

```
#define DC_VALUE_RATIO 0.2
```

```
5 long number_freqs = 4;
```

```
double freq[10] = {
```

```
    1.9,
```

```
    1.654,
```

```
10    1.476,
```

```
    1.227
```

```
};
```

```
double phase[10] = {
```

```
    2.111,
```

```
    0.0765,
```

```
    1.32,
```

```
    1.0,
```

```
    2.38,
```

```
20    0.73,
```

```
    3.0,
```

```
    1.1
```

```
};
```

STAMP_IT.C

```

/* this program explores the specifics of stamping an image with 'digital
reticles' for the purpose of
5 determining registration between a given image and the digimarc signatures,
i.e., the registration
requirements for finding the scale and rotation elements of the ubiquitous
snowy image patterns */

```

10

```

#include "pinecone.h"
#include "freqs.h"

```

```

#define DISPLAY_IT 1
#define PI 3.141592653589
#define SQRT2_2 0.707106781186
#define INITIAL_SCALE 10.0

```

```

unsigned char *img;
long xdim,ydim;
Colorindex *disp;
Colorindex *scale_disp;
Colorindex *pdisp;

```

```

int helplines = 2;
char *help[] =
{

```

```

30     "usage: stamp_it filename xdim ydim channels \n",
    "\n stamp_it modifies the input image to include digital reticles and
outputs filename.stamped "
};

```

35

```

int load_scale_disp(void){
long i,j;

    pdisp = scale_disp+20;

```

```

    for(j=0;j<15;j++){
        for(i=1;i<20;i++){
            *pdisp = (unsigned char)255;
            pdisp += 20;
5          }
          pdisp += 20;
        }
        pdisp = scale_disp+20+(35*400);
        for(j=0;j<15;j++){
10          for(i=1;i<20;i++){
                *pdisp = (unsigned char)255;
                pdisp += 20;
            }
            pdisp += 20;
15        }
    }
    return(0);
}

int draw_scale(double value){
20  long i;
    double dtemp;

    value *=10.0;

25    memcpy(dispen, scale_disp, 40000);
    dtemp = 20.0 * value;
    if(dtemp > 399.0)dtemp=399.0;
    pdisp = &dispen[15*400 + (int)dtemp];
    for(i=0;i<20;i++){
30        *pdisp = (unsigned char)255;
        pdisp += 400;
    }
    rectwrite(0,0,399,49,dispen);

35  return(0);
}
```

```

double calculate_change( double distance , double scale , long which ){
    long i;
    double value=DC_VALUE_RATIO * scale;

5      for(i=0;i<number_freqs;i++){
            value += scale * sin ( freq[i] * distance + phase[i] +
(double)which * PI );
        }
        if(value < 0.0)value = 0.0;

10     return(value);
}

```

```

15     main( argc, argv )
int      argc ;
char     *argv[] ;
{
20     long i,j,go=1,button,channels,which,count;
    long temp,increment,last_middle;
    unsigned char tmp,*pimg,*pimgl,*img_out,*img_r,*img_b;
    char string[80], outfile[80];
    FILE *inf;
25     double change,current_scale = INITIAL_SCALE;
    long gid_img,gid_stamped,gid_scale;

    if(argc!=5) {
        for(j=0;j<helplines;j++)fprintf( stderr, "%s", help[j]) ;
30         exit( 1 ) ;
    }

    xdim = atoi(argv[2]);
    ydim = atoi(argv[3]);
35     channels = atoi(argv[4]);
    if(channels != 1 && channels !=3){
        fprintf( stderr, "stamp_it : channels must equal 1 for B/W or
3  for color\n" ) ;
        exit( 1 ) ;
    }

```

```

}
```

```

if(DISPLAY_IT) disp = calloc(xdim*ydim, sizeof(Colorindex) ) ;
```

```

else disp = calloc(40000, sizeof(Colorindex) ) ;
```

```

5 scale_disp = calloc(40000, sizeof(Colorindex) ) ;
```

```

img = calloc(xdim*ydim, sizeof(unsigned char) ) ;
```

```

img_out = calloc(xdim*ydim, sizeof(unsigned char) ) ;
```

```

if( !disp || !scale_disp || !img || !img_out ){
```

```

    fprintf( stderr, "stamp_it : can not allocate space\n" ) ;
```

```

10     exit( 1 ) ;
```

```

}
```

```

if(channels == 3){
```

```

    img_r = calloc(xdim*ydim, sizeof(unsigned char) ) ;
```

```

15    img_b = calloc(xdim*ydim, sizeof(unsigned char) ) ;
```

```

    if( !img_r || !img_b ){
```

```

        fprintf( stderr, "stamp_it : can not allocate space\n"
```

```

    ) ;
```

```

        exit( 1 ) ;
```

```

20    }
```

```

}
```

```

/* read in binary data into array */
```

```

inf = fopen(argv[1],"r");
```

```

if(!inf) {
```

```

    fprintf(stderr,"stamp_it: can't open %s\n",argv[1]);
```

```

    exit(1);
```

```

}
```

```

30 if(channels == 3){
```

```

    fread(img_r,sizeof(unsigned char),xdim*ydim,inf);
```

```

    fread(img,sizeof(unsigned char),xdim*ydim,inf);
```

```

    fread(img_b,sizeof(unsigned char),xdim*ydim,inf);
```

```

}
```

```

35 else fread(img,sizeof(unsigned char),xdim*ydim,inf);
```

```

fclose(inf);
```

```

/* flip it */
```

```

pimg = img;
```

```

pimg1 = &img[xdim*(ydim-1)];
for(i=0;i<(ydim/2);i++){
    for(j=0;j<xdim;j++){
        tmp = *pimg;
5         *(pimg++) = *pimg1;
        *(pimg1++) = tmp;
    }
    pimg1 -= (2*xdim);
10 }

if(DISPLAY_IT){
    foreground();
    prefsizex(xdim,ydim);
    gid_img = winopen("Original");
    gflush();

    pdisp = disp;
    pimg = img;
20 for(i=0;i<(ydim*xdim);i++){
        *(pdisp++) = (Colorindex)*(pimg++);
    }
    rectwrite(0,0,xdim-1,ydim-1,disp);

    prefsizex(xdim,ydim);
    gid_stamped = winopen("Stamped Image...");
    rectwrite(0,0,xdim-1,ydim-1,disp);

    load_scale_disp();
30 prefsizex(400,50);
    gid_scale = winopen("Rough scaling...");
}

/* main visual feedback loop */
last_middle = 0;
while(go){
35

```

```

/* first diagonal */
for(i=0;i<(xdim+ydim-1);i++){
    which = 0;
    /* calculate addition or subtraction to image */
    change = calculate_change( (double)i * SQRT2_2 ,
5    current_scale,  which );
    if( i < xdim ){
        pimg = &img[i*xdim];
        pimg1 = &img_out[i*xdim];
10        count = i+1;
    }
    else {
        pimg = &img[xdim*ydim - ydim - xdim + i + 1];
        pimg1 = &img_out[xdim*ydim - xdim - ydim + i +
15    1];
        count = xdim + ydim - i - 1;
    }
    for(j=0;j<count;j++){
        temp = (long)*pimg + (long)(change+0.5);
        if(temp > 255)temp = 255;
        *pimg1 = (unsigned char)temp;
        pimg -= (xdim-1);
        pimg1 -= (xdim-1);
20    }
    }
/* second diagonal */
for(i=0;i<(xdim+ydim-1);i++){
    which = 1;
    /* calculate addition or subtraction to image */
    change = calculate_change( (double)(xdim - 1 - i) *
30    SQRT2_2 , current_scale, which );
    if( i < xdim ){
        pimg1 = &img_out[xdim - i - 1];
        count = i+1;
35    }
    else {
        pimg1 = &img_out[(i-xdim+1)*xdim];
        count = xdim+ydim-i-1;
    }
}

```



```

5      for(j=0;j<count;j++){
          temp = (long)*pimg1 + (long)(change+0.5);
          if(temp > 255)temp = 255;
          *pimg1 = (unsigned char)temp;
          pimg1 += (xdim+1);
      }
    }

10    if(DISPLAY_IT){
        pdisp = disp;
        pimg = img_out;
        for(i=0;i<(ydim*xdim);i++){
            *(pdisp++) = (Colorindex)*(pimg++);
        }
        winset(gid_stamped);
        rectwrite(0,0,xdim-1,ydim-1,disp);

        pdisp = disp;
        pimg = img;
        for(i=0;i<(ydim*xdim);i++){
            *(pdisp++) = (Colorindex)*(pimg++);
        }
        winset(gid_img);
        rectwrite(0,0,xdim-1,ydim-1,disp);

        winset(gid_scale);
        draw_scale(current_scale);
    }

30    button=0;
    while(!button){
        if( getbutton(LEFTMOUSE) ){
            current_scale *= 1.15;
            button = 1;
            last_middle = 0;
        }
        if( getbutton(RIGHTMOUSE) ){
            current_scale *= 0.85;

```

```

        button = 1;
        last_middle = 0;
    }
    if( getbutton(MIDDLEMOUSE) ){
5       while( getbutton(MIDDLEMOUSE) );
        if( last_middle ){
            button = 1;
            go=0;
        }
10       last_middle = 1;
    }
}

/* now re-sign output image because of slight changes to master key */

/* flip output image */
pimg = img_out;
20 pimg1 = &img_out[xdim*(ydim-1)];
for(i=0;i<(ydim/2);i++){
    for(j=0;j<xdim;j++){
        tmp = *pimg;
        *(pimg++) = *pimg1;
        *(pimg1++) = tmp;
    }
25 pimg1 -= (2*xdim);
}

/* write out signed image */
30 sprintf(outfile,"%s.stamped",argv[1]);
inf = fopen(outfile,"w");
if(!inf) {
    fprintf(stderr,"stamp_it: can't open %s\n",outfile);
35     exit(1);
}
if(channels == 3){
    fwrite(img_r,sizeof(unsigned char),xdim*ydim,inf);
    fwrite(img_out,sizeof(unsigned char),xdim*ydim,inf);
}

```

```
        fwrite(img_b,sizeof(unsigned char),xdim*ydim,inf);
    }
    else fwrite(img_out,sizeof(unsigned char),xdim*ydim,inf);
    fclose(inf);
```

5

```
    /* free and clean up */
    if(DISPLAY_IT) gexit();
    free(img);
    free(img_out);
    free(disg);
    free(scale_disg);
    if( channels = 3){
        free(img_r);
        free(img_b);
    }
```

10

15

}

REGISTR.C

```

/* this program is a companion to stamp_it, wherein it is given a suspect
image and it attempts to determine where
5 the cross-hatch pattern resides within the suspect image, thereby determining
the scale, roation and offset
of the suspect image */

10 #include "pinecone.h"
#include "freqs.h"

#define DISPLAY_IT 1
#define DISP_POW 0.1
15 #define MOV_AV 21 /* keep this odd please */
#define MAGG_THRESHOLD 1.7
#define ANGLE_INCREMENT (PI/360.0)
#define START_SCALE_ZONE 50
#define SCALE_START 0.5
20 #define SCALE_STOP 2.0
#define SCALE_STEP 0.001
#define MAX_BLOCK_SIZE 5
#define PI 3.141592653589

25 unsigned char *img;
long xdim,ydim;
Colorindex *disp;
Colorindex *pdisp;
long bits,fftdim,fft_size;
30 float *ar,*ai;
float wr[10000],wi[10000];

int helplines = 2;
char *help[] =
35 {
    "usage: register filename xdim ydim channels \n",
    "\n register looks at the input image for digital reticles and
displays registered result "
};

```

```

int shift_array(float *array,int dim){
    int i,j;
    int dim2 = dim/2;
    int offset = dim2*dim + dim2;
5    float *p1,*p2,ftmp;

    for(i=0;i<dim2;i++){
        p1 = &array[i*dim];
        p2 = &array[offset+i*dim];
10        for(j=0;j<dim2;j++){
            ftmp = *p1;
            *p1 = *p2;
            *p2 = ftmp;
            p1++;p2++;

15        }
    }
    offset = dim2*dim;
    for(i=0;i<dim2;i++){
        p1 = &array[dim2+i*dim];
        p2 = &array[offset+i*dim];
20        for(j=0;j<dim2;j++){
            ftmp = *p1;
            *p1 = *p2;
            *p2 = ftmp;
            p1++;p2++;

25        }
    }
    return(0);
}

30
int block_filter(float *array,int dim){
    int i,j,k,l,i2;
    float buffer[2][4096];

35    for(i=0;i<dim;i++)buffer[0][i] = array[i];
    for(i=1;i<(dim-1);i++){
        i2 = i%2;
        buffer[i2][0] = array[i*dim];
        buffer[i2][dim-1] = array[i*dim+dim-1];

```

```

        for(j=1;j<(dim-1);j++){
            buffer[i2][j]=0.0;
            for(k=-1;k<2;k++){
                for(l=-1;l<2;l++){
5              buffer[i2][j]+= array[(i+k)*dim +
                (j+l)];
            }
        }
        buffer[i2][j]/=9.0;
10      }
        i2 = (i-1)%2;
        for(j=0;j<dim;j++)array[(i-1)*dim + j] = buffer[i2][j];
    }
    i2 = (i-1)%2;
15    for(j=0;j<dim;j++)array[(i-1)*dim + j] = buffer[i2][j];

    return(0);
}

20

/* assumes fftdim arrays ar and ai */
double get_mag(double x, double y){
25    long xoff,yoff;
    float *par,*pai;
    double xdist,ydist,cf,r_value,i_value,value=0.0;

    xoff = (long)x;
30    yoff = (long)y;
    xdist = x - (double)xoff;
    ydist = y - (double)yoff;

    par = &ar[yoff * fftdim + xoff];
35    pai = &ai[yoff * fftdim + xoff];

    cf = (1.0 - xdist) * (1.0-ydist);
    r_value = (double)*(par++);
    i_value = (double)*(pai++);

```

```

value = cf * sqrt(r_value*r_value + i_value*i_value);
cf = xdist * (1.0-ydist);
r_value = (double)*par;
i_value = (double)*pai;
5 value += cf * sqrt(r_value*r_value + i_value*i_value);
par += (fftdim-1);
pai += (fftdim-1);

cf = (1.0 - xdist) * ydist;
10 r_value = (double)*(par++);
i_value = (double)*(pai++);
value += cf * sqrt(r_value*r_value + i_value*i_value);
cf = xdist * ydist;
r_value = (double)*par;
15 i_value = (double)*pai;
value += cf * sqrt(r_value*r_value + i_value*i_value);

return(value);
}

20
25
main( argc, argv )
int    argc ;
char    *argv[] ;
{
30    long i,j,k,go,channels,count,center;
    long dim,angle_int,total_angles,top_candidate;
    unsigned char tmp,*pimg,*pimgl,*img_out,*img_r,*img_b;
    char string[80], outfile[80];
    FILE *inf;
35    long gid_img;
    double
x,y,cos,sinn,angle,mag,magg[5000],magg_ma[5000],angle_vector[10000];
    double radius,dtmp,dscale,grey_diff,highest,frac,highest_scale,scale;
    float *par,*pai;

```

```

    if(argc!=5) {
        for(j=0;j<helplines;j++)fprintf( stderr, "%s", help[j]) ;
        exit( 1 ) ;
    }

    xdim = atoi(argv[2]);
    ydim = atoi(argv[3]);
    channels = atoi(argv[4]);
    if(channels != 1 && channels !=3){
10         fprintf( stderr, "register : channels must equal 1 for B/W or
3 for color\n" ) ;
        exit( 1 ) ;
    }

15     /* find the next power of two equal to or higher than the highest
input dimension */
    if(xdim > ydim)dim = xdim;
    else dim = ydim;
    fftdim = 1; go = 1; bits = 0;
20     while( go ){
        if( dim > fftdim ){
            fftdim*=2;
            bits++;
        }
        else go = 0;
    }
    if(bits > 12){
30         fprintf( stderr, "recognize : sorry, this particular program
only accepts 4K images and less\n" ) ;
        exit( 1 ) ;
    }
    fft_size = fftdim * fftdim;

    disp = calloc(fft_size, sizeof(Colorindex) ) ;
35     img = calloc(xdim*ydim, sizeof(unsigned char) ) ;
    ar = calloc(fft_size, sizeof(float) ) ;
    ai = calloc(fft_size, sizeof(float) ) ;
    if( !disp || !img || !ar || !ai ){
        fprintf( stderr, "register : can not allocate space\n" ) ;
    }

```



```

        exit( 1 ) ;
    }

    if(channels == 3){
5       img_r = calloc(xdim*ydim, sizeof(unsigned char) ) ;
        img_b = calloc(xdim*ydim, sizeof(unsigned char) ) ;
        if( !img_r || !img_b ){
            fprintf( stderr, "register : can not allocate space\n"
) ;
10         exit( 1 ) ;
        }
    }

    /* read in binary data into array */
15    inf = fopen(argv[1],"r");
    if(!inf) {
        fprintf(stderr,"register: can't open %s\n",argv[1]);
        exit(1);
    }
20    if(channels == 3){
        fread(img_r,sizeof(unsigned char),xdim*ydim,inf);
        fread(img,sizeof(unsigned char),xdim*ydim,inf);
        fread(img_b,sizeof(unsigned char),xdim*ydim,inf);
    }
25    else fread(img,sizeof(unsigned char),xdim*ydim,inf);
    fclose(inf);

    /* flip it */
    pimg = img;
30    pimg1 = &img[xdim*(ydim-1)];
    for(i=0;i<(ydim/2);i++){
        for(j=0;j<xdim;j++){
            tmp = *pimg;
            *(pimg++) = *pimg1;
35            *(pimg1++) = tmp;
        }
        pimg1 -= (2*xdim);
    }

```

```

/* copy image buffer into ar */
par = ar;
pimg = img;
for(i=0;i<ydim;i++){
5       for(j=0;j<xdim;j++){
           *(par++) = (float)*(pimg++);
       }
       par += (fftdim-xdim);
}

10
/* 2d fft, in place */
printf("\nforward fft... \n");
fft2d(ar,ai,bits,0,wr,wi);
printf("done \n.... ");
15 shift_array(ar,fftdim);
shift_array(ai,fftdim);
center = fftdim/2;

/*
20 block_filter(ar,fftdim);
block_filter(ai,fftdim);

*/

if(DISPLAY_IT){
    foreground();
    prefsiz(fftdim,fftdim);
    gid_img = winopen("yahh");
    gflush();

    dtmp =
30 (double)ar[center*fftdim+center+1]*(double)ar[center*fftdim+center+1];
    dtmp +=
(double)ai[center*fftdim+center+1]*(double)ai[center*fftdim+center+1];
    dscale = pow(dtmp, DISP_POW);

35 pdisp = disp;
par = ar;
pai = ai;
for(i=0;i<(fftdim*fftdim);i++){

```

```

                                dtmp = pow( (*par * *par + *pai * *pai) ,
DISP_POW );

                                dtmp *= (255.0 / dscale);
                                if(dtmp>255.0)dtmp = 255.0;
5                                *(pdisp++) = (Colorindex)( dtmp );
                                par++;pai++;
                                }
                                rectwrite(0,0,fftdim-1,fftdim-1,disp);
                                }

10                                /* now search for the gross rotation axes */
                                for(angle = 0.0,angle_int = 0;angle<PI/2;angle+=ANGLE_INCREMENT,
                                angle_int++){

15                                coss = cos(angle);
                                sinn = sin(angle);
                                /* fill radial vector */
                                for(i=0;i<(fftdim/2);i++){
                                    radius = (double)i;
                                    x = (double)center - radius * coss;
20                                    y = (double)center - radius * sinn;
                                    mag = get_mag(x,y);
                                    x = (double)center + radius * sinn;
                                    y = (double)center - radius * coss;
                                    mag += get_mag(x,y);
25                                    magg[i] = mag;
                                }
                                /* create moving average */
                                magg_ma[MOV_AV/2] = 0.0;
                                for(i=0;i<MOV_AV;i++){
30                                    magg_ma[MOV_AV/2] += magg[i];
                                }
                                magg_ma[MOV_AV/2] /= ( (double)MOV_AV );
                                for(i=(MOV_AV/2)+1;i<(fftdim/2)-(MOV_AV/2)-1;i++){
                                    magg_ma[i] = magg_ma[i-1];
35                                    magg_ma[i] -= ((magg[i - (MOV_AV/2) -
1]))/(double)MOV_AV);
                                    magg_ma[i] += ((magg[(MOV_AV/2) + i])/(double)MOV_AV);
                                }

```

```

/* within prescribed 'scale zone', calculate final number for
this angle */

```

```

angle_vector[angle_int] = 0.0;
for(i=START_SCALE_ZONE;i<(fftdim/2) - (MOV_AV/2) -1;i++){
    mag = magg[i] / magg_ma[i];
    if( mag > MAGG_THRESHOLD ){
        mag -= MAGG_THRESHOLD;
        angle_vector[angle_int] += (mag*mag);
    }
}

```

```

}
total_angles = angle_int;

```

```

/* sort out the TOP_CANDIDATES and find which has the best match on
absolute scale */

```

```

/* choose the highest angle_vector number for starters */
highest = 0.0;
for(angle_int=0;angle_int<total_angles;angle_int++){
    if(angle_vector[angle_int]>highest){
        highest = angle_vector[angle_int];
        top_candidate = angle_int;
    }
}

```

```

printf("\n\n tilt from original found = %d ", (top_candidate/2) -
45);

```

```

coss = cos(ANGLE_INCREMENT * (double)top_candidate);
sinn = sin(ANGLE_INCREMENT * (double)top_candidate);
/* fill radial vector for this angle */
for(i=0;i<(fftdim/2);i++){
    radius = (double)i;
    x = (double)center - radius * coss;
    y = (double)center - radius * sinn;
    mag = get_mag(x,y);
    x = (double)center + radius * sinn;
    y = (double)center - radius * coss;
    mag += get_mag(x,y);
    magg[i] = mag;
}

```

```

    }
    /* create moving average */
    magg_ma[MOV_AV/2] = 0.0;
    for(i=0;i<MOV_AV;i++){
5         magg_ma[MOV_AV/2] += magg[i];
    }
    magg_ma[MOV_AV/2] /= ( (double)MOV_AV );
    for(i=(MOV_AV/2)+1;i<(fftdim/2)-(MOV_AV/2)-1;i++){
10         magg_ma[i] = magg_ma[i-1];
        magg_ma[i] -= ((magg[i - (MOV_AV/2) - 1])/(double)MOV_AV);
        magg_ma[i] += ((magg[(MOV_AV/2) + i])/(double)MOV_AV);
    }
    /* now slide the scale and find the highest point */
    highest = 0.0;
15     for(scale = SCALE_START;scale < SCALE_STOP;scale+=SCALE_STEP){
        mag = 0.0;
        for(j=0;j<number_freqs;j++){
            radius = scale * freq[j] * (double)fftdim / PI / 2.0;
            if( (int)radius <= (1+MOV_AV/2) || (int)(radius+1) >=
20             ((fftdim/2) - (MOV_AV/2) - 1) );
                else {
                    frac = radius - (double)( (int) radius);
                    mag += (1.0-frac)*(magg[ (int)radius ] /
25                     magg_ma[ (int)radius ]);
                    mag += frac*(magg[ (int)(radius+1) ] /
                     magg_ma[ (int)(radius+1) ]);
                }
            }
            if(mag > highest){
30                 highest = mag;
                highest_scale = scale;
            }
        }
        printf("\n\nscale found = %lf    \n",1.0/highest_scale);
35
    }

    /* now find the exact offset and orietnation, i.e. if it is flipped,
    etc. */

```

```
/* display the result at correct rotation and pixel size */
```

```
sleep(1000);
```

```
5
```

```
/* free and clean up */
```

```
if(DISPLAY_IT) gexit();
```

```
free(img);
```

```
free(dis);
```

```
10
```

```
free(ar);
```

```
free(ai);
```

```
if( channels == 3){
```

```
    free(img_r);
```

```
    free(img_b);
```

```
}
```

```
}
```